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Fifteen Years of Hawksbill Sea Turtle (*Eretmochelys imbricata*) Nesting in Northern Brazil

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ABSTRACT. – We present long-term data for hawksbill (*Eretmochelys imbricata*) nesting in the 2 main rookeries in Brazil: 1) northern Bahia and Sergipe, where the estimated number of nests laid each year increased from 199 in the 1991–1992 nesting season to 1345 in the 2005–2006 season and 2) Rio Grande do Norte, where the estimated number of nests laid in the 2005–2006 season was around 185–475. Adding these results, we estimate that the number of hawksbill nests laid in the 2 main Brazilian nesting grounds in 2005–2006 was between 1530 and 1820 nests. Data on the percentage of hawksbill clutches kept in situ by season in each rookery are also presented. The apparent increasing trend in hawksbill nesting in northern Brazil is encouraging and seems to reflect a range of conservation measures implemented over the past 25 years.

KEY WORDS. – Reptilia; Testudines; Cheloniidae; *Eretmochelys imbricata*; sea turtle; reproduction; nesting; conservation; Brazil

The hawksbill sea turtle (*Eretmochelys imbricata*; "tartaruga-de-pente" in Portuguese) has a circumglobal distribution in tropical areas of the Atlantic, Indian, and Pacific oceans (Márquez 1990). This species, a natural resource widely exploited since ancient times (Frazier 2003) and with high commercial value (Campbell 2003), is currently classified as Critically Endangered by the World Conservation Union (IUCN; Meylan and Donnelly 1999), and is included in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; CITES 2007).

In Brazil, hawksbills nest mainly on the northern coast of the state of Bahia (Marcovaldi et al. 1999) and in the contiguous state of Sergipe (Fig. 1). Another important area has recently been recognized, located in the eastern part of the state of Rio Grande do Norte (Fig. 1). There are other minor nesting areas in the states of Espírito Santo (<10 nests/y; Brazilian Sea Turtle Conservation Program of the Chico Mendes Institute for Biodiversity Conservation [Projeto TAMAR-ICMBio], *unpubl. data*), Paraíba (about 50 nests/y; Mascarenhas et al. 2003, 2004), and Ceará (about 15 nests/y; Lima 2002) (Fig. 1). The hawksbill turtle is included on the Brazilian government's official list of endangered species (IBAMA 2003) and all life history stages, including eggs and hatchlings, are fully protected by law in Brazil.

In this article we present data gathered by Projeto TAMAR-ICMBio (Marcovaldi et al. 2005) regarding hawksbill nesting in northern Bahia and Sergipe between 1991–1992 and 2005–2006. We also present an estimate of the annual number of hawksbill nests in the state of Rio Grande do Norte, where TAMAR has maintained an experimental station since 2000. Data on the percentage of hawksbill clutches kept in situ by season in each area are also presented.

METHODS

Study Areas and Periods. — In northern Bahia and Sergipe, Brazil, the study area comprises 339 km of beaches between lat 10°31°S (the mouth of the São Francisco River, at the border between the states of Sergipe and Alagoas) and lat 12°28°S (Salvador, the state of Bahia capital; Fig. 1). TAMAR maintains 7 field stations in this region. A central portion of Sergipe's coast, stretching for 20 km around Aracaju, the state of Sergipe capital, is not monitored—nowadays, a small number of sea turtle nestings occur in that area, possibly as a result of anthropic actions. The coastline of Sergipe is composed of high-energy beaches with an open, rock-free offshore approach. In northern Bahia, much of the coastline consists of sandy beaches with rocks and coral reefs located close to shore. The study area is characterized by white to light-yellow, coarse to fine-grained sand.

Nesting in Bahia and Sergipe occurs mainly during the austral summer, so each nesting season is denoted by a 2-year code, e.g. 1994–1995. Although some sea turtle nests are found in all months of the year, the start of each season has been arbitrarily defined as 1 August. TAMAR started operating in that region in 1982, protecting nests, hatchlings, and nesting females initially at Praia do Forte, Bahia, and Pirambu, Sergipe, and later extending its activities to the whole study area in these states. However, we restricted our analyses to the period from 1991–1992 to

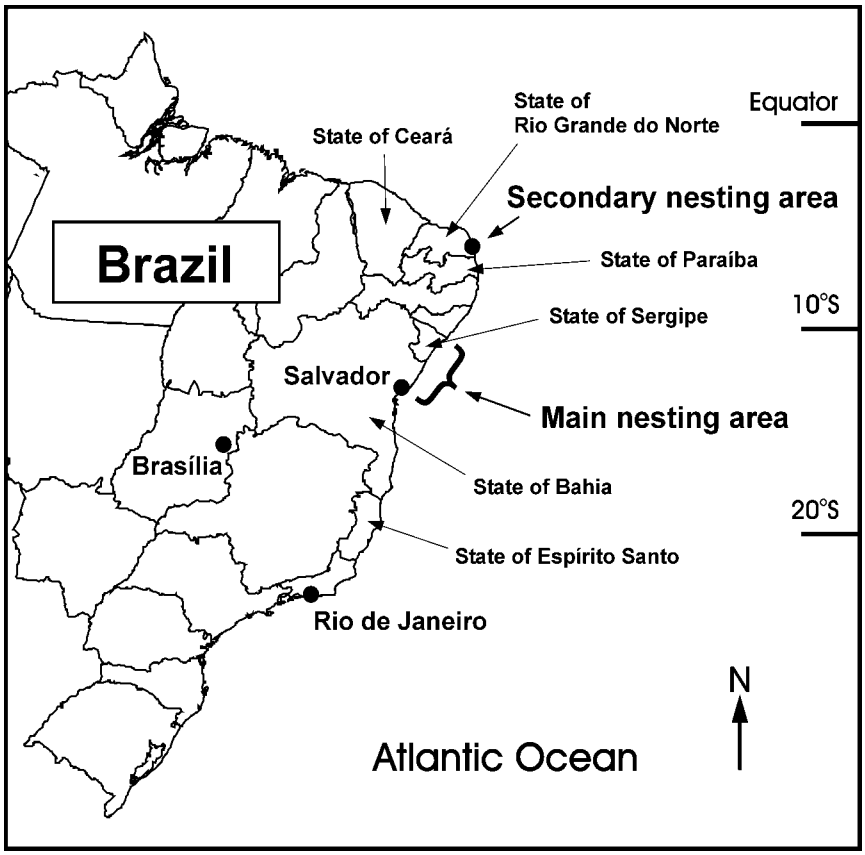

Figure 1. Map of Brazil, indicating the main nesting area for hawksbills, located in northern Bahia and Sergipe, and a secondary nesting area located in the state of Rio Grande do Norte. Other Brazilian states with minor hawksbill nesting areas are also shown.

2005–2006 (15 nesting seasons), because availability of data for the whole study area began in 1991–1992.

In the state of Rio Grande do Norte, the study area includes 32 km of beaches between lat 5°52′S and lat 6°41′S, about 60 km south of Natal, the state capital (Fig. 1). A central part of the study area, about 9 km located around Pipa, has been steadily monitored from 2001–2002 to 2005–2006, whereas monitoring for other parts of the study area started in 2004–2005 and lasted for only 1 or 2 nesting seasons. The coastline of the study area in Rio Grande do Norte alternates between sandy beaches and cliffs up to 40 m high, often with rocks and reefs located close to shore. Beaches are characterized by fine-grained, white-yellowish sand.

Data Collection. — In Bahia and Sergipe, TAMAR's regular fieldwork is carried out from 15 September to 15 March, and in Rio Grande do Norte, from 15 September to 30 July. Field methodology has been described in detail elsewhere (Marcovaldi et al. 1999, 2005; Almeida and Mendes 2007). The entire study area is monitored daily at dawn by experienced fishers hired by TAMAR and working under the supervision of TAMAR's technical personnel. Patrolling fishers look for nests laid the night before and for each encountered track, efforts are made to determine if a nest is present by digging up the sand to reveal presence or absence of eggs. An added benefit to patrols is that this activity on the beach inhibits egg poaching. Daily patrolling of the beaches by TAMAR's technical personnel is also carried out in the early morning to mark nests found by fishers with numbered stakes and to excavate hatched nests. TAMAR's goal has been to leave every nest in situ. However, clutches deemed to be threatened by predators, heavy beach traffic, beach erosion, or egg poaching (currently occurring at very low levels; about 1%–2% of all clutches) are relocated to open-air hatcheries or to other beach sections.

All nests are excavated within 24 hours after the majority of hatchlings have emerged. Clutch size is determined by counting egg shells and unhatched eggs, and the species is determined, if possible, by examining dead hatchlings, embryos, or live hatchlings remaining in the nest. In this article, we also use data on clutches identified as belonging to other species or not identified to species when estimating the total number of hawksbill clutches in each season; more explanation follows below. In Bahia and Sergipe, data obtained from each clutch include species identification, date and location of laying, management strategy, clutch size, hatching success, and incubation period. In the state of Rio Grande do Norte, in the region around Pipa, clutches were identified to species using TAMAR's standardized methodology. In other parts of the study area in that state, nests were counted on the beach by local fishers and volunteers. Because they were not recorded by qualified TAMAR personnel, we cannot

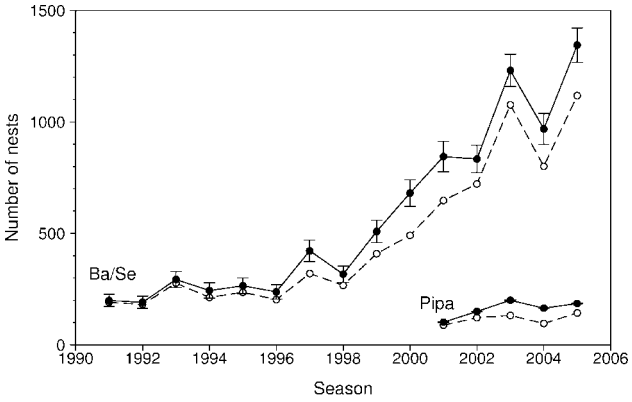

Figure 2. Number of hawksbill nests by season. In the 2 upper curves, white dots = number of hawksbill nests recorded ($n = 7154$) in Bahia and Sergipe (Ba/Se), 1991–1992 to 2005–2006; black dots = number of estimated nests ($n = 8582$) in that region and period. In the 2 lower curves, white dots = number of hawksbill nests recorded ($n = 581$) in the region of Pipa, Rio Grande do Norte, 2001–2002 to 2005–2006; black dots = number of estimated hawksbill nests ($n = 802$) in that region and period. Error bars indicate 95% point-wise confidence intervals (note that the error bars for Pipa are very close to the estimated points). The first year of each season is shown, e.g., 1992 = 1992–1993.

definitively identify species; however, we feel confident in the total number of nests. Furthermore, beach monitoring in Rio Grande do Norte, outside Pipa, was carried out for a minimum of 3 days a week but not on a daily basis.

Data Analyses. — To estimate the total number of hawksbill nests laid in Bahia and Sergipe, data for each season were analyzed separately for each TAMAR station in that region, and the results for all stations were then summed to estimate the total number of nests in the season. For each station and season, the estimate of the total number of hawksbill nests was obtained by adding the number of confirmed hawksbill nests (actually recorded on the beach and identified as laid by hawksbills) to the number of hawksbill nests estimated from recorded nests of unknown species. To estimate the number of hawksbill nests from recorded nests of unknown species, the number of recorded nests of unknown species was multiplied by the ratio of the number of confirmed hawksbill nests to the number of confirmed nests of known species. This has been done on the assumption that the nests for which the species was known represented a random sample of the nests laid in the station area.

For each season and station, an estimate of the variance of the estimate of the number of hawksbill nests was obtained by applying the formula for random sampling in Rice (2007, p. 212). All nests were used in this analysis, regardless of whether they were left in situ, transferred to an open air hatchery, or relocated to a different section of the beach.

Finally, an estimate of the total number of hawksbill nests laid in Bahia and Sergipe in each season was obtained by adding the estimates obtained for each station. An estimate of the variance of the estimate of the total number of hawksbill nests in the season was obtained by adding the estimated variances for each station per season on the assumption that the data were obtained independently for each station (Rice 2007, p. 140). This allowed us to calculate a standard 95% normal confidence interval for the estimated number of hawksbill nests in the season. To estimate the total number of hawksbill nests laid in each season in the region of Pipa, state of Rio Grande do Norte, the same method was used as for Bahia and Sergipe, but there was only 1 station to consider. In each nesting area, the percentage of hawksbill nests kept in situ in each season was computed on the basis of the number of confirmed hawksbill nests in the season, not on the basis of the estimated number of hawksbill nests.

Tests for trend on the number of nests per season and on the percentage of nests kept in situ per season were performed by means of nonparametric, nonseasonal Mann-Kendall tests (Hipel and McLeod 1994). Statistical analyses and the estimation procedure were carried out by means of the software R 2.4.1 (R Development Core Team 2006).

RESULTS

Hawksbill nesting in Bahia and Sergipe occurs mostly (97.7% of the nests) from November to March, with the greatest number of nests (79.8%) between December and February. In Rio Grande do Norte, nesting occurs mostly (98.8% of the nests) from November to April, with a peak (about 80%) from January to March.

In Bahia and Sergipe, the estimated number of nests per season changed from 199 in the 1991–1992 nesting season to 1345 in 2005–2006, a nearly 7-fold increase in 15 years (Fig. 2); the overall increasing trend is statistically significant (nonseasonal Mann-Kendal test, tau = 0.829, $p < 0.0001$, $n = 15$). However, Fig. 2 shows an apparent difference in the behavior of the time series before and after 1996–1997; there is not a significant trend between 1991–1992 and 1996–1997 (nonseasonal Mann-Kendal test, tau = 0.2, $p = 0.707$, $n = 6$), whereas there is a significant trend between 1996–1997 and 2005–2006 (nonseasonal Mann-Kendal test, tau = 0.867, $p < 0.001$, $n = 10$).

Most (95.0%) of the nests actually recorded ($n = 7154$) were found in Bahia, and only 5.0% were found in Sergipe. Nesting activity is most common in the south: among 339 km of beaches, 77.6% of the total number of nests were recorded in the southernmost 77 km (the area managed by the TAMAR stations Arembepe and Praia do Forte, both in the state of Bahia).

The percentage of clutches kept in situ in Bahia and Sergipe changed from 16.2% in 1991–1992 to 60.9% in 2005–2006 (Fig. 3); the increasing trend is significant (nonseasonal Mann-Kendal test, tau = 0.619, $p < 0.002$, $n = 15$).

In the region of Pipa in Rio Grande do Norte, 813 nests were recorded between 2001–2002 and 2005–2006. A total of 589 nests were identified to species, among which 581 were hawksbills, corresponding to 98.6% of the

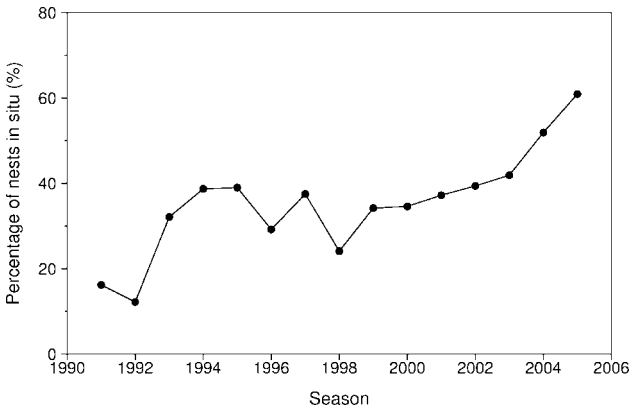

Figure 3. Percentage of hawksbill clutches kept in situ by season, Bahia and Sergipe, 1991–1992 to 2005–2006.

number of nests identified to species. Through the estimation procedure detailed above, we estimate that 802 hawksbill nests were laid in the region between 2001–2002 and 2005–2006. Estimates of the number of nests by season for the region of Pipa are presented in Fig. 2; the estimated number of nests varied between 102 in 2001–2002 and 200 in 2003–2004.

Although 188 nests were recorded in 2005–2006 in the region around Pipa (of which 185 are estimated to belong to hawksbills), an additional 294 nests were recorded in the same season in other areas of the state of Rio Grande do Norte close to the region of Pipa. We do not have the species identification of these, but if we assume that 98.6% of them belong to hawksbills, we would have 290 hawksbill nests in that area in 2005–2006. This value is likely an underestimate, however, because beach monitoring in that area was not carried out on a daily basis. We estimate that the number of hawksbill nests in the whole study area in Rio Grande do Norte in 2005–2006 was between 185 and 475 nests, and the upper bound is possibly an underestimate. In the whole study area, about 84% of the clutches were kept in situ, and 16% were relocated to other areas of the beach.

The experimental station in Rio Grande do Norte has been working only since 2001–2002 and beach monitoring has been uneven among the seasons in that state. The available data do not allow us to assess the temporal trend in the number of nests per season.

Adding the results presented so far, we estimate that the number of hawksbill nests laid in the 2 main Brazilian nesting grounds in 2005–2006 was between 1530 and 1820 nests.

DISCUSSION

In a review by Meylan (1999) of the status of the hawksbill sea turtle in the Caribbean region (including Colombia, Venezuela, Mexico, and the United States), where data gathered up to 1998 from 35 geopolitical units were presented, the annual number of estimated nests per geopolitical unit varied from 1–2 to more than 3000, although no estimates are available for many geopolitical units. Hawksbill populations were reported to be declining or depleted in 22 of 26 geopolitical units for which status and trend information were available (no nesting occurred in 3 additional units). Only 2 geopolitical units had more than 800 estimated nests/y: Cuba and Mexico. In Cuba, nesting was estimated by Moncada et al. (1999) at 1700–3400 nests/y around 1998, with an unclear trend, and was estimated at 2000–2500 nests around 2001 (CITES, 2002). In the Yucatán Peninsula in Mexico there were about 4500 reported nests in 1996, with an increasing trend in 1977–1996 (data from beach surveys in Campeche, Yucatán and Quintana Roo; Garduño-Andrade et al. 1999).

Along the Atlantic coast of South America east of Venezuela, hawksbills also nest in Guyana (low-density nesting, no countrywide estimate available), Suriname (about 30 nests/y) and French Guiana (<5 nests/y) in addition to Brazil (Meylan 1999).

The estimated number of hawksbill nests at the 2 main nesting grounds in Brazil during the 2005–2006 season (1530–1820 nests) places the Brazilian nesting population among the largest in the western Atlantic. Since 1996, there has been a nearly steady increasing trend in the estimated number of nests per season in the area monitored by TAMAR in Bahia and Sergipe, the area with the greatest number of nests. In Rio Grande do Norte, we are not able to assess the temporal trend yet, although the region around Pipa should be taken as an index area in the future, where continued monitoring of the beaches would produce reliable data to assess trends.

No direct estimates of the period of time hawksbills take to mature are available (CITES 2002). Studies on juvenile growth suggest that this may take as much as 15–20 years or more for populations in the Western Atlantic (Boulon 1994; Diez and van Dam 2002) and >25 years elsewhere (Chaloupka and Limpus 1997; M. Chaloupka, *pers. comm.*, 2007). An average period of time to sexual maturity for hawksbills of at least 25 years has been taken as a working estimate by Meylan and Donnelly (1999) for conservation purposes. The increase in the number of nests in Bahia and Sergipe became more pronounced in 1996 and since then it has been occurring at about the same rate (Fig. 2). Since 1997, Brazil's data fall within the range of estimates (according to available knowledge) for the age at maturity of hawksbills in the Atlantic, because TAMAR started operating in the above mentioned areas in 1982. This suggests that the increase in the number of nests observed in Bahia and Sergipe could be, at least in part, the result of TAMAR's conservation actions (protection of nests, hatchlings, and nesting females) in those areas. The sex ratios of hawksbill nests in Bahia are strongly female biased, which could also contribute to a faster increase in the number of nests (Godfrey et al. 1999).

Genetic analyses of mitochondrial DNA from Bahia indicate that hawksbills nesting in Brazil are genetically isolated from other populations in the western Atlantic, thus

representing a separate stock (Bass 1999; Bowen et al. 2007). This distinctiveness and the fact that the conservation of long-lived late-maturing species such as the hawksbill require long-term conservation efforts (Bjorndal 1999) point to the importance of maintaining conservation actions directed at hawksbill populations in Brazil.

Hays (2004) showed that there are currently some examples of success stories in sea turtle conservation in several regions of the world, apparently as a result of the implementation of long-term conservation programs. Such programs were initiated to combat extensive human exploitation of eggs and turtles on nesting beaches and threats such as habitat alteration, pollution of the sea, and incidental capture of sea turtles in fisheries (Lutcavage et al. 1997). As pointed out by Hays (2004), some examples where marked increases in population numbers on nesting beaches have been recorded are the conservation of green turtles (*Chelonia mydas*) in Hawaii (Balazs and Chaloupka 2004), Costa Rica (Bjorndal et al. 1999), and, in the Atlantic, Ascension Island (United Kingdom) (Godley et al. 2001). To that list should be added the conservation of leatherback sea turtles 247 (*Dermochelys coriacea*) in St. Croix, U.S. Virgin Islands in the Caribbean (Dutton et al. 2005). In Brazil, besides the increase in hawksbill nesting in Bahia and Sergipe, significant increases in nesting populations have also been recorded for leatherbacks (*Dermochelys coriacea*) in the state of Espírito Santo (Thomé et al. 2007), for olive ridley sea turtles (*Lepidochelys olivacea*) in the states of Sergipe and Bahia (da Silva et al., 2007), and for loggerhead sea turtles (*Caretta caretta*) in the states of Bahia and Espírito Santo (Marcovaldi and Chaloupka 2007). These increases are likely due, at least in part, to the conservation actions by TAMAR over the past 25 years in Brazil. These cases indicate that some depleted sea turtle populations have the potential for relatively rapid (i.e., on the order of 15–30 years) recovery once conservation measures are implemented (Balazs and Chaloupka 2004; Hays 2004).

The conservation of sea turtles is often a matter not just for local efforts but also for international collaboration (Trono and Salm 1999; Crowder 2000; Hays 2004). Genetic studies indicate that hawksbills found in feeding areas in the Caribbean could originate in part from nesting beaches in Bahia (P. Lara-Ruiz, *unpubl.data*). It is also known that the hawksbill feeding aggregation found in the Fernando de Noronha Archipelago and in Rocas Atoll in northern Brazil (Marcovaldi et al. 1998; Sanches and Bellini 1999) is a mixed stock with contributions from Brazilian, Caribbean, and African rookeries (P. Lara-Ruiz, *unpubl.data*). Furthermore, there is some evidence, obtained through conventional flipper tagging, of a connection between hawksbills inhabiting Fernando de Noronha and western Africa (Bellini et al. 2000; Grossman et al. 2007). The connections mentioned above suggest that the fate of the Brazilian hawksbill nesting population could be dependent on conservation efforts not only in Brazil but also in the Caribbean and western Africa. Further studies are needed on the population structure of hawksbills in the Atlantic, which could guide future conservation actions.

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